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The Use of Geometric Morphometrics as a New Method to Analyse Glenoid Bone Loss after Shoulder Dislocation

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Abstract

Background - Glenoid bone loss occurs at the anteroinferior and posteroinferior aspects of the glenoid rim in anterior and posterior instability respectively. This morphological change in the shape of the glenoid fossa predisposes to increasing instability.

Aim - The aim of this study was to use geometric morphometrics to quantify changes to glenoid morphology in traumatic shoulder instability.

Methods - 3D models of the surface of the glenoid fossa were created using CT scans from 8 patients with 5 dislocations and 3 controls. Ten landmarks, corresponding to the same anatomical sites between samples were digitized onto the surface of the glenoid fossa. Shape information was extracted from the landmark co-ordinates and analysed for variation in the geometric properties of the glenoid fossa using geometric morphometrics.

Results - Results showed that the areas of most pronounced variation between the dislocation and control groups were as expected, at the anteroinferior, and posteroinferior glenoid regions.

Conclusions - This indicated that geometric morphometrics allows variation in the geometric properties of the glenoid fossa after dislocation to be accurately analysed at a good level of detail in three dimensions.

Clinical Relevance - Compared to conventional techniques using single glenoid measurements from 2 dimensional images, morphometrics represents an exciting new avenue for analysing the morphological changes to the glenohumeral joint involved in shoulder pathology.

Introduction

Bony Bankart lesions are common and described in up to 71% of individuals following anterior shoulder dislocation.[6] The extent of bone loss increases with number of dislocations.[21] In posterior shoulder dislocation, the opposite occurs with bone loss from the posterioinferior aspect of the glenoid rim as shown in Figure 1.[10,20] The extent of bony bankart lesions is widely dependent on the method of injury with high impact injury in contact sports hypothesized to result in most extensive bone loss.[4,23] The decrease in articular surface area and loss of uniform concavity of the glenoid fossa acts to de-stabilize the glenohumeral joint and increase the risk of re-dislocation.[22]

Clinically the extent of bone loss is important for planning the appropriate surgical treatments to re- stabilise the shoulder joint in an individual who has experienced multiple re-dislocations.[1,11] In these patients, Computed Tomography (CT) is the imaging modality of choice in the quantification of glenoid bone loss with a high sensitivity of 93%.[8,17] Accurate CT interpretation by a radiologist involves viewing 2D slices of the glenohumeral joint which can also be used to form a 3D reconstruction of the joint. Quantification of glenoid bone loss is largely

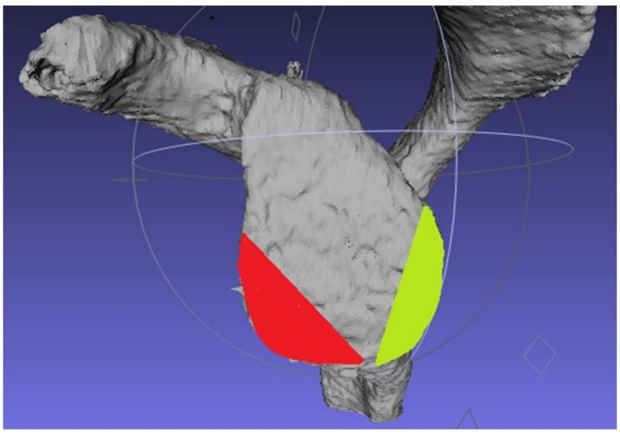

Figure 1: *A 3D model of the glenoid fossa from the control group indicating the most common areas of bone loss after glenohumeral dislocation.*
Red - Shows the Anterioinferior aspect of the glenoid fossa where bony bankart lesions are common after anterior dislocation.
Green – Shows the Posteroinferior aspect of the glenoid fossa where reserve bony bankart lesions are common after posterior dislocation.

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subjective based on the radiologists overall clinical impression and no exact criteria are used in analysis of bone loss. Several novel studies used sagittal views of the glenoid to compare which typical features of glenoid bone loss most closely relate to rate of re-dislocation.[8,2] Of three measurements for quantifying bone loss; cross sectional area, maximum glenoid width and maximum glenoid length, the most statistically significant was reduction in maximum glenoid width.[2] These measurement techniques based on single measurements taken are still relatively crude and few studies using more detailed and accurate ways to quantify glenoid bone loss are reported in the literature.

Morphometrics is a method for defining the shape of an object taking into account all features with the object with the exclusion of size, orientation and position.[5,15] The object or specimen, in this case a 3D CT image of the glenoid fossa is represented in a form that can analysed using morphometrics by digitising a number of landmarks over the surface of the object. These landmarks each represent the same equivalent point from the surface of the glenoid. Landmarking functions to provide unique information from each specimen but corresponding shape information across the dataset to represent the morphology of the glenoid fossa.[5,15] Shape information is extracted by closely aligning the landmark points using a method known as procrustes superimposition.[5]

This study aims to use morphometrics as a more accurate method for quantification of changes in glenoid morphology following shoulder dislocation. The primary objective of this study is to assess if geometric morphometrics can be used to quantify a significant morphological change in the glenoid fossa after glenohumeral dislocation. The secondary aim is to determine if there is a critical quantitative change in glenoid morphology corresponding to each number of glenohumeral joint re-dislocations.

Materials and Methods

Dataset

This was a retrospective study using CT scans of 8 patients all with a history of shoulder pathology. For the control group, patients were required to have no previous shoulder pathology involving the glenoid fossa with no history of instability. Of the 4 patients initially selected for the control group one was excluded due to previous history of suspected instability described in the patient's notes. Patients were divided into two categories, the control group (n=3) and the dislocation group (n=5). The control group included 2 males and 1 female with an age range 21-57, mean age of 39 years, each with a CT scan of one shoulder. This gave 3 sets of CT images, two left and one right with a range of shoulder pathologies but no bony pathology to the glenoid. The dislocation group included 5 males with an age range 26-44 years with a mean age of 34 years. All patients in this group had dislocated their right shoulder, 3 anterior dislocations and 2 posterior dislocations. All patients in the dislocation group had received stabilisation surgery. Any CT scans taken after surgery, were after bankart repair of the labrum, which involves no glenoid bone replacement. Of the patients who had undergone the bone replacement technique known as the Latarjet procedure, all CT scans were taken pre-operatively before surgery altered the bony morphology of the glenoid.

3D model formation

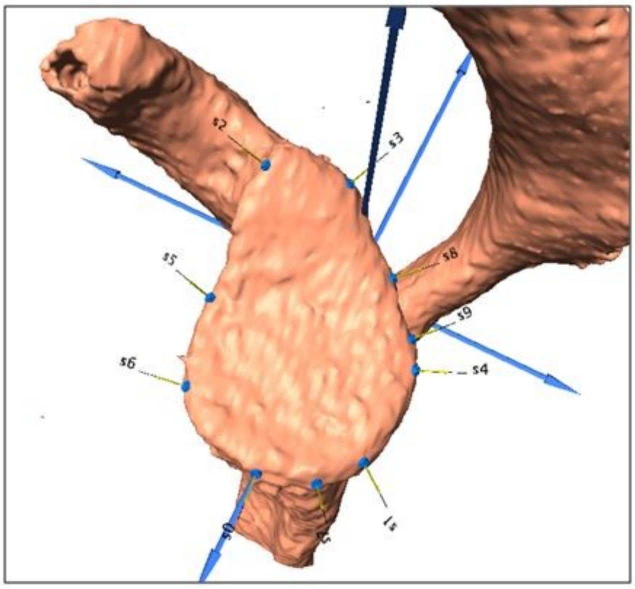

Figure 2: *A 3D model of the surface of the glenoid fossa from the control group. The location of the landmark points are indicated by the blue circles and numbered according to the description.*

Anonymised CTs were obtained as a stack of 2D CT .dicom format images for each of the 8 patients. These were viewed using the freeware 3D slicer software.[18] Using the editor module of this software package, segmentation of each set of dicom images was achieved. Segmentation was carried out manually by using a threshold value. The threshold value for each image was individually determined by using the grayscale value from the centre of the glenoid fossa on the axial view. All voxels in the source volume in the range that had been selected by the threshold value were then labeled. Using these segmented images, the model maker module was used to create a 3D representation of the glenohumeral joint which was exported in the .stl file format.[18] Using the Meshlab software these files were individually imported.[3] The 3D model was cropped involving removal of all bones separate from the scapula, principally the humerus and acromion. Removal of the humerus allowed a clear view of the glenoid fossa. Some of the CT images were CT arthrograms, these were included due to the small number of available scans. In these cases the radioopaque dye used in the arthrogram is highlighted by image segmentation as it has a similar density and therefore grey value to bone. The areas infiltrated by the dye were deleted to leave a clearly defined glenoid fossa and glenoid rim. These 3D surface mesh models were exported in the .ply file format. A set of 10 landmarks were digitized onto the glenoid fossa in three dimensions using Landmark version 1.3.0.[25] Landmarks were chosen to correspond to sites identifiable across all 9 glenoids as shown in Table 1 and displayed in Figure 2.

Landmark	Position
S 0	anterior aspect of the infraglenoid tubercle
S 1	posterior aspect of the infraglenoid tubercle
S 2	anterior aspect of the supraglenoid tubercle
S 3	posterior aspect of the supraglenoid tubercle
S 4	most posterior aspect of the posterior glenoid curvature
S 5	most medial aspect of the anterior glenoid curvature
S 6	most anterior aspect of the anterior curvature
S 7	midpoint of the infraglenoid tubercle
S 8	point of posterior curvature in line with the superior aspect of the spine of the scapula
S 9	point of posterior curvature in line with the inferior aspect of the spine of the scapula

Table 1: *Details the position of the 10 landmarks digitized onto the glenoid fossa.*

Landmark points were chosen which represented areas of the glenoid rim marked by features common to the glenoid area of the scapula across specimens. The supraglenoid and infraglenoid fossa were chosen as there is little variation in these sites between individuals. The supraglenoid tubercle represents this insertion of the long head of biceps tendon and the inferior glenoid tubercle the insertion of the long head of the triceps.[9] Other landmarks were chosen to give a good spread of points around the glenoid rim particularly at the posteroinferior and anteroinferior edge where bone loss is most common following posterior and anterior dislocation respectively. The landmark points were individually digitised onto the surface mesh of each glenoid fossa to ensure accurate placement. Landmark co-ordinate values in the X,Y and Z axis were then exported in the .dta file format.

Shape Analysis - Geometric morphometrics was used to quantify the variation in shape of the glenoid fossa between the control and dislocation group using the MorphoJ morphomterics software.[16] To quantify the shape difference, co-ordinates of the landmarks digitized onto the surface of the glenoid fossa were extracted. Shape of an object is defined as the objects geometric properties with the exclusion of size, position and orientation.[15] For the quantification of shape variation, Procrustes superimposition of the landmark points was performed. Variation between the configurations of landmarks digitized onto the glenoid fossa after procrustes superimposition is entirely due to variation in the geometric properties of the object.[5] To achieve this, Procrustes superimposition excludes the contribution of size, position and orientation in three steps.[14] Firstly the landmarks from the glenoid fossa are scaled to a unit size.[12] Secondly the landmark configurations are moved to a common position and thirdly are rotated to the position of best fit so there is minimal distance between all the landmark points.[12] This gives the procrustes fit for the landmark configuration. Some landmarks have more variation than others. Procrustes fit acts to average this variation, so shape variation is spread out as evenly as possible between individual landmark points of the landmark configuration.[13] Using the procrustes fit a wireframe graph was used to show variation of the landmarks points between the control and dislocation groups. A wireframe graph simply connects the landmark points so the position and variation of the landmarks points can be visualised.

Principal component (PC) analysis was used to analyse shape variation from the landmark configurations of all the glenoid fossa used in the study. PC analysis which examines patterns of variation between data points in a multidimensional space allows the major patterns of variation to be visualised in a graphical form.[16]

Results

From the scatter of PC scores shown for both the dislocation group and control group in Figure 3, a number of observations can be made. The outer extremes of PC scores are connected to show the maximum variation in each group. Firstly the scatter of PC scores shows there is greater variation in the shape of the glenoid fossa seen in the dislocation group compared to the control group. Secondly it shows that there is overlap in the geometric properties of the control group compared to the dislocation group.

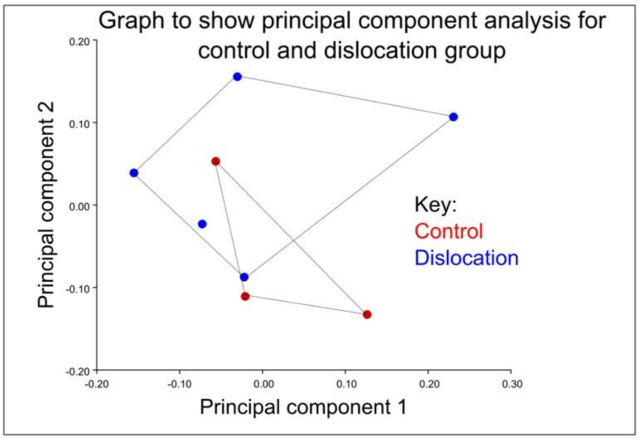

Figure 3: *A graph to show the principal component analysis for the shape of the Glenoid Fossa. Scatter points include both the control and the dislocation group. Each point represents a plot of the Principal component score for one sample.*

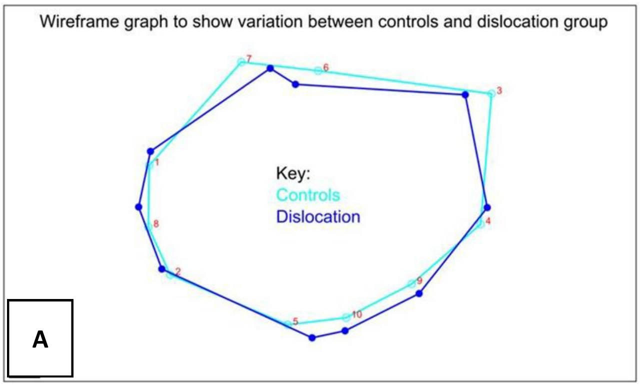

Figure 4 (A): *A wireframe graph to show the variation of the landmark configurations representing the shape variation of the glenoid fossa between the control and dislocation groups.Orientation the same as the glenoid fossa in figure 4(B).*

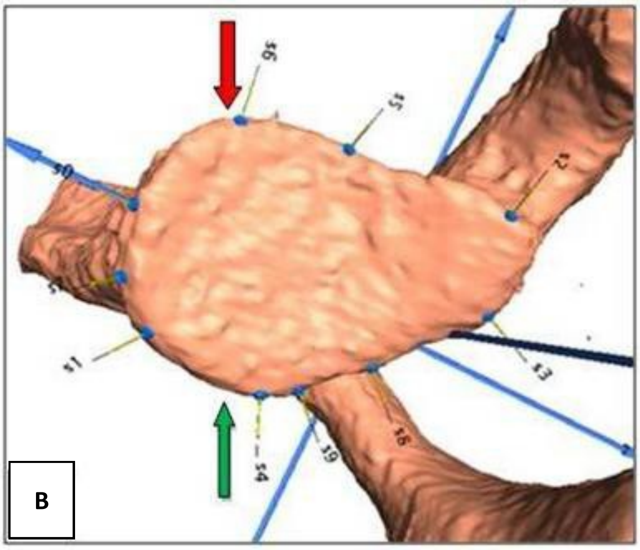

Figure 4 (B): *3D model of a left glenoid fossa from the control group to provide anatomical context and orientation for the landmark points digitized onto the glenoid surface. The green arrow pointing to the normal posterior edge and the red arrow to the normal anterior edge. Each number on the wireframe graph corresponds to the landmark number from the 3D model +1.*

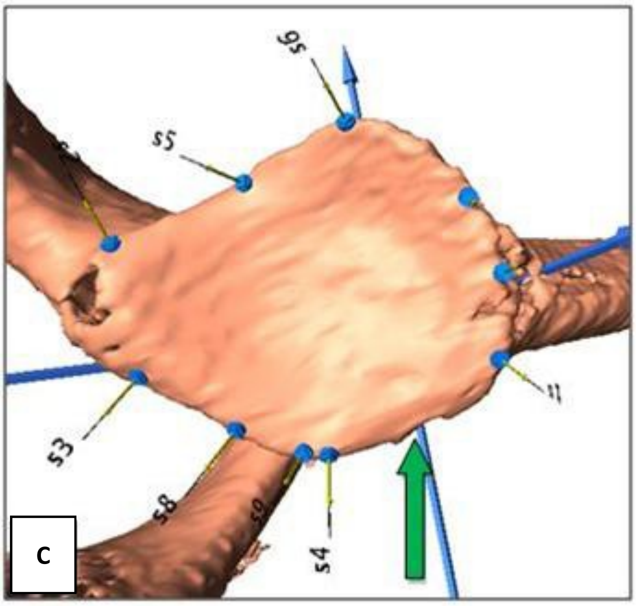

Figure 4 (C): *3D model of a right glenoid fossa with the most severe bone defect at the posteroinferior aspect of the glenoid rim following recurrent posterior dislocation. Green arrow marks the area of posterior flattening of the glenoid rim as a result of bone loss.*

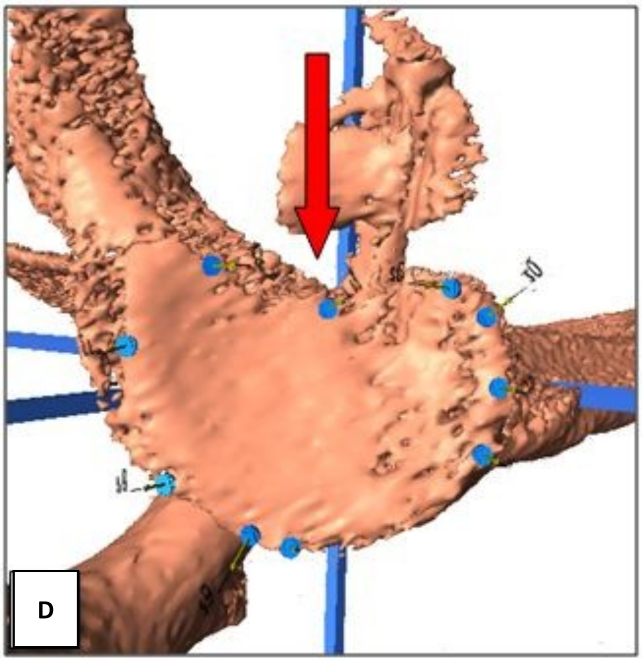

Figure 4 (D): *3D model of a right glenoid fossa with the most severe bone defect at the anterior aspect of the glenoid rim. Fractured loose bone can be seen separate from the glenoid rim as a result of recurrent anterior dislocations. Red arrow marks the area of flattening to the anterior glenoid rim to the extent that it is now concave in nature.*

Anterior glenoid Rim

The wireframe graph in Figure 4(A) comparing the landmarks of the control and dislocation groups highlights a number of areas of the glenoid fossa where variation is seen. In the dislocation group there is considerable movement of point 6 (marking the most medial aspect of the anterior glenoid curvature) and point 7 (marking the most anterior part of the anterior curvature) towards each other compared to the control group. In the control group the graph shows the glenoid rim as a normal convex shape, whereas in the dislocation group, the contour of the anterior glenoid rim is concave at its midpoint. This suggests an overall morphological change in the anterior curvature of the glenoid rim. Figure 4(D) a model of a glenoid from the dislocation group with recurrent anterior instability shows a large bony deficit from the anterior glenoid rim. The normal contour of the anterior edge of the glenoid is concave in nature due to extensive bone loss. Comparing this to a normal control glenoid fossa shown in Figure 4(B) where the contour of the anterior glenoid rim is convex demonstrates the general trend seen in the wireframe graph of 4(A).

Posterior Glenoid Rim

In the wireframe graph points 9, 10, 5 and 2 along the posterior edge of the glenoid rim demonstrate differing trends in the contour of the posterior rim of the glenoid fossa between the control and dislocation groups. The posterosuperior aspect of the glenoid rim has a similar contour between the dislocation and control group. However at the posteroinferior aspect of the glenoid rim in the dislocation group, point 2 (marking the posterior aspect of the glenoid rim) and point 5 (marking the most posterior aspect of the posterior glenoid tubercle) are further away from each other compared to the control group. This gives the appearance of an increased flattening of the posterior-inferior glenoid rim. The morphology of the posterior glenoid rim after posterior dislocation can be directly seen by comparing Figure 4(B) (a normal glenoid) to Figure 4(C) (a glenoid from a patient with recurrent posterior dislocation). Here the green arrow of Figure 4(C) shows flattening of the posteroinferior aspect of the glenoid rim compared to the same region of Figure 4(B) where the posterior rim is convex in nature. This comparison supports the general trend of posteroinferior glenoid rim flattening in the dislocation group compared to the control group seen in the wireframe graph.

Discussion

Several studies have tried to find a critical level of bone loss to relate to the number of dislocations.[7,8] One study proposed a critical level of bone loss at 13.4% below which the average number of re-dislocations were 6.3 and above which the average number of dislocations were 10.1.[8] This seems a rather arbitrary figure and provides no real clinical relevance for the treatment of shoulder dislocation. The reason that these conclusions with few useful applications exist is due to a large variability in bone loss after dislocation between individuals. The PC scatter results showed large variation in glenoid shape after dislocation with the wireframe graph showing most variation at the anterior-inferior and posterior-inferior glenoid rim. This variation is most likely due to the varying degrees of glenoid bone loss between the samples of the dislocation group. Even in individuals with the same number of dislocations bone loss varies greatly due to factors such as the force of impact of the injury and the exact mechanism of injury.[19] This explains why extensive variation is seen in the glenoid morphology of the dislocation group in this study and also why it is so difficult to relate the extent of bone loss to the number of re-dislocations.

A number of different techniques have been used to measure the shape of the glenoid particularly in relation to pathological glenoid morphology following dislocation. In anterior dislocation a common feature of anteroinferior glenoid bone loss is the flattening of the anterior curvature.[6,8,24] Studies have utilized this feature to quantify bone loss after traumatic anterior shoulder dislocation by measurements such as the length of an anterior straight line and reduced maximum glenoid width[7]. In one study reduced maximum width was shown to be clinically significant in relation to re-dislocation rates. However, these measurements based on 2 dimensional images only take into account a small proportion of the 3 dimensional angled surface of the glenoid fossa.[2] A study investigating glenoid morphology related to atraumatic posterior dislocation used CT images to measure tilting angles of the glenoid as a measure of glenoid concavity.[10] The glenoid was classified using these measurements as concave, flat or convex. Results showed the glenoid was the conventional concave shape in 78% of the controls with no history of instability.[10] However the patients in the dislocation group almost all had glenoid bony changes such as glenoid retroversion resulting in a flattened or convex glenoid surface.[10] Results from our study showed that using morphometric analysis to compare the control group to the dislocation group; it accurately identified the areas of glenoid bony deficit both antero-inferiorly and postero-inferiorly in the patients with anterior and posterior dislocation respectively. We therefore believe the use of geometric morphometrics represents a more complete method for analysing glenoid morphology. Using a single measure from a 2 dimensional image or measuring angles to give an overall interpretation of the morphology of the glenoid fossa provides only limited shape information. The method of landmarking and morphometric analysis takes into account a wider range of geometric components from the glenoid. Morphometrics using landmarks digitized around the glenoid therefore offers a more comprehensive three dimensional analysis of glenoid morphology. Results from this study show that using geometric morphometrics, variation of each of the landmark points can be analysed to give information about variation in glenoid morphology at different regions of the glenoid fossa. In addition this information can be combined to examine geometric variation of the glenoid fossa as a whole when comparing morphology before and after dislocation.

There were limitations of this study. The technique is new and challenging to undertake at the moment. Also, the dataset is too small to make any statistically valid conclusions on the amount of glenoid bone loss significant and relevant to aid treatment decisions. Further exploration into the use of morphometrics to study glenoid morphological changes is required.

Conclusions

Despite the limitations of the study a number of valuable conclusions can still be drawn from this project. The results show that geometric morphometrics has many advantages over other techniques which have been reported in the literature to analyse changes to glenoid morphology. Morphometric analysis of a three dimensional surface representation of the glenoid fossa provides much more extensive data for analysis of glenoid geometry. This study showed areas where variation is most common at the anteroinferior and posteroinferior aspects of the glenoid fossa following anterior and posterior dislocation respectively. The techniques used in this study highlights possibilities to analyse glenohumeral morphology to a high level of geometric detail in a wide number of shoulder pathologies. In addition, morphometrics could help establish which variations in glenoid morphology occurring naturally in the population predispose to certain groups of shoulder pathology. Further research using morphometrics to quantify shoulder morphology has exciting potential as an additional tool for determining the surgical management of patients with recurrent dislocation.

Acknowledgments

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References:

1. Bollier MJ, Arciero R. Management of glenohumeral bone loss. Sports Med Arthrosc Rev. 2010;18(3):140-148.
2. Chaung TY et al. Use of Preoperative three-dimensional computed tomography to quantify glenoid bone loss in shoulder instability. Arthroscopy. 2008;24:376-382.
3. Cignoni P et al. 2011. Meshlab (Version 1.3.0) [Computer software]. Retrieved March 15th 2011. Available from http://meshlab.sourceforge.net.
4. Cutts S, Prempeh M, Drew S. Anterior shoulder dislocation. Ann R Coll Surg Engl. 2009;91:2-7.
5. Drake AG, Klingenberg CP. Large-scale diversification of skull shape in domestic dogs: disparity and modularity. Am. Nat. 2010;175:289-301.
6. Edelson JG. Bony changes of the glenoid as a consequence of shoulder instability. J Shoulder Elbow Surg. 1996;5:293-298.
7. Griffith JF et al. Anterior shoulder dislocation: Quantification of glenoid bone loss with CT. AJR. 2003;180:1423-1430.
8. Griffith JF et al. Prevalence, Pattern and spectrum of glenoid bone loss in anterior shoulder dislocation: CT analysis of 218 patients. AJR. 2008;190:1247-1254.
9. Halder AM, Itoi E, An KN. Anatomy and biomechanics of the shoulder. Orthop Clin North Am. 2000;31(2):159-176.
10. Inui H et al. Glenoid shape in atraumatic posterior instability of the shoulder. Clin Orthop Relat Res. 2002;403:87-92.
11. Itoi E et al. The effect of a glenoid defect on anteroinferior stability of the shoulder after Bankart repair: a cadaveric study. J Bone Joint Surg Am. 2000;82(1):35-46.
12. Klingenberg CP, Leamy LJ, Cheverud JM. Integration and modularity if quantitative trait locus effects on geometric shape in the mouse mandible. Genetics. 2004;166:1909-1921.
13. Klingenberg CP, 2010. Analysis of organismal form BIOL 30111: Unit 4, Procrustes Superimposition. Retrieved March 10th , 2011 from: https://blackboard.manchester.ac.uk.
14. Klingenberg CP, 2010. Analysis of organismal form BIOL 30111: Unit 7- Principal components. Retrieved March 10th , 2011 from https://blackboard.manchester.ac.uk.
15. Klingenberg, C P. Evolution and development of shape: integrating quantitative approaches. Nature Reviews Genetics. 2010;11:623–635.
16. vKlingenberg CP. 2011. MorphoJ: an integrated software package for geometric morphometrics. Molecular Ecology Resources, advance online publication.
17. Kwon YW et al. Use of three-dimensional computed tomography for the analysis of the glenoid anatomy. J Shoulder Elbow Surg. 2005;14(1):85-90.
18. Pieper S et al. 2011, 3D Slicer (Version 3.6.3) [Computer Software]. Retrieved March 15th 2011. Available from http://www.slicer.org.
19. Robinson CM et al. Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. J Bone Joint Surg Am. 2006;88:2326-2336.
20. Saupe N et al. Acute traumatic posterior shoulder dislocation: MR findings. Radiology. 2008;248(1):185-93.
21. Sugaya H et al. Glenoid rim morphology in recurrent anterior shoulder instability. J Bone Joint Surg Am. 2003;85(5):878-884.

22. Taylor DC, Arciero RA. Pathologic changes associated with shoulder dislocations. Arthroscopic and physical examination findings in first time, traumatic anterior dislocations. Am J Sports Med. 1997;25:306-311.
23. Wang RY, Arciero RA. Treating the athlete with anterior shoulder instability. Clin Sports Med. 2008;27(4):731-748.
24. Wiedemann E, Jager A, Nebelung W. Pathomorphology of shoulder instability. Orthopade. 2009;38(1):16-20,22-23.
25. Wiley DF et al. 2005. Landmark (Version 3.0) [Computer Software]. Retrieved March 15th 2011. Available from http://www.idav.ucdavis.edu/research/projects/EvoMorph/.

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